# COMPARISONS OF HYDROLOGY, GEOLOGY, AND PHYSICAL CHARACTERISTICS BETWEEN

## TENDERFOOT CREEK EXPERIMENTAL FOREST, MONTANA (EAST SIDE)

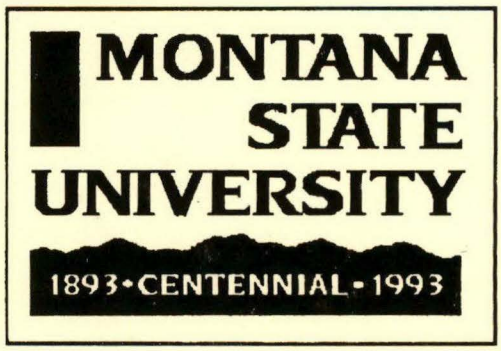
## AND

## CORAM EXPERIMENTAL FOREST, MONTANA (WEST SIDE)

Final Report
RJVA-INT-92734

June 1995



# COMPARISONS OF HYDROLOGY, GEOLOGY, AND PHYSICAL CHARACTERISTICS BETWEEN TENDERFOOT CREEK EXPERIMENTAL FOREST (EAST SIDE) MONTANA, AND CORAM EXPERIMENTAL FOREST (WEST SIDE) MONTANA

Final Report
RJVA-INT-92734

Between

U.S. Department of Agriculture
Forest Service
Intermountain Research Station
Forestry Sciences Laboratory
Bozeman, Montana

and

Montana State University
College of Letters and Sciences
Department of Earth Sciences
Bozeman, Montana



June 1995

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This research was supported in part by funds provided by the Intermountain Research Station, U.S. Forest Service, U.S. Department of Agriculture.

Metric Conversion

English units are used in this report to have data compatible to that being collected by lead Federal agencies and others for stream flow (US Geological Survey), snow pack (Natural Resources [formerly Soil] Conservation Service), precipitation (National Weather Service), and land units and elevations (US Forest Service and US Geological Survey). Following are conversion factors for converting to metric:

CONVERSION FACTORS

| Multiply | By | To obtain |
|---|---|---|
| acre | 0.4047 | hectare |
| acre-foot (acre-ft, AC-FT) | 0.001233 | cubic hectometer |
| cubic foot ($ft^3$) | 0.02832 | cubic meter |
| cubic foot per second (cfs) | 0.02832 | cubic meter per second |
| foot (ft) | 0.03048 | meter |
| inch (in.) | 2.54 | centimeter |
| mile (mi) | 1.609 | kilometer |
| square mile ($mi^2$) | 2.59 | square kilometer |

Degree Fahrenheit (°F) may be converted to degree Celsius (°C) by using the following equation: °C = 5/9 (°F-32).

The following items and abbreviations also are used in this report:

microsiemens per centimeter at 25 degrees Celsius ($\mu S/cm$)
milligram per liter (mg/L)

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## INTRODUCTION

There are two experimental forests in Montana established by the U.S. Department of Agriculture, Forest Service, Intermountain Research Station (INT)(Fig. 1). Both experimental forests are administered by INT's Research Work Unit, RWU-4151, Silviculture of Subalpine Forest Ecosystems.

Tenderfoot Creek Experimental Forest (TCEF) is east of the Continental Divide and is located 24 miles north of White Sulphur Springs and 9 miles northwest of Highway 89 at Kings Hill in central Montana. All of the 8,874 acre (area obtained from Lewis and Clark National Forest Geographic Information System) experimental forest drains into Tenderfoot Creek which flows westerly into the Smith River and then into the Missouri River and into the Mississippi River system. The administrative headquarters for TCEF is located at the Intermountain Research Station's Forestry Sciences Laboratory in Bozeman, Montana. The majority of the hydrologic data for TCEF was compiled by Farnes, McCaughey, and Hansen (1995).

Coram Experimental Forest (CEF) is west of the Continental Divide and is located 28 miles northeast of Kalispell and 5 miles south of the west entrance of Glacier National Park in northwestern Montana. Most of the 7,423 acre (area obtained from Flathead National Forest Geographic Information System) experimental forest drains into Abbot Creek which flows westerly after leaving CEF into the Flathead River and then into the Columbia River system. The administrative headquarters for CEF is located at the Intermountain Research Station's Forestry Sciences Laboratory in Missoula, Montana. Most of the hydrologic data for CEF was compiled by Farnes, Shearer, and Hansen (1995).

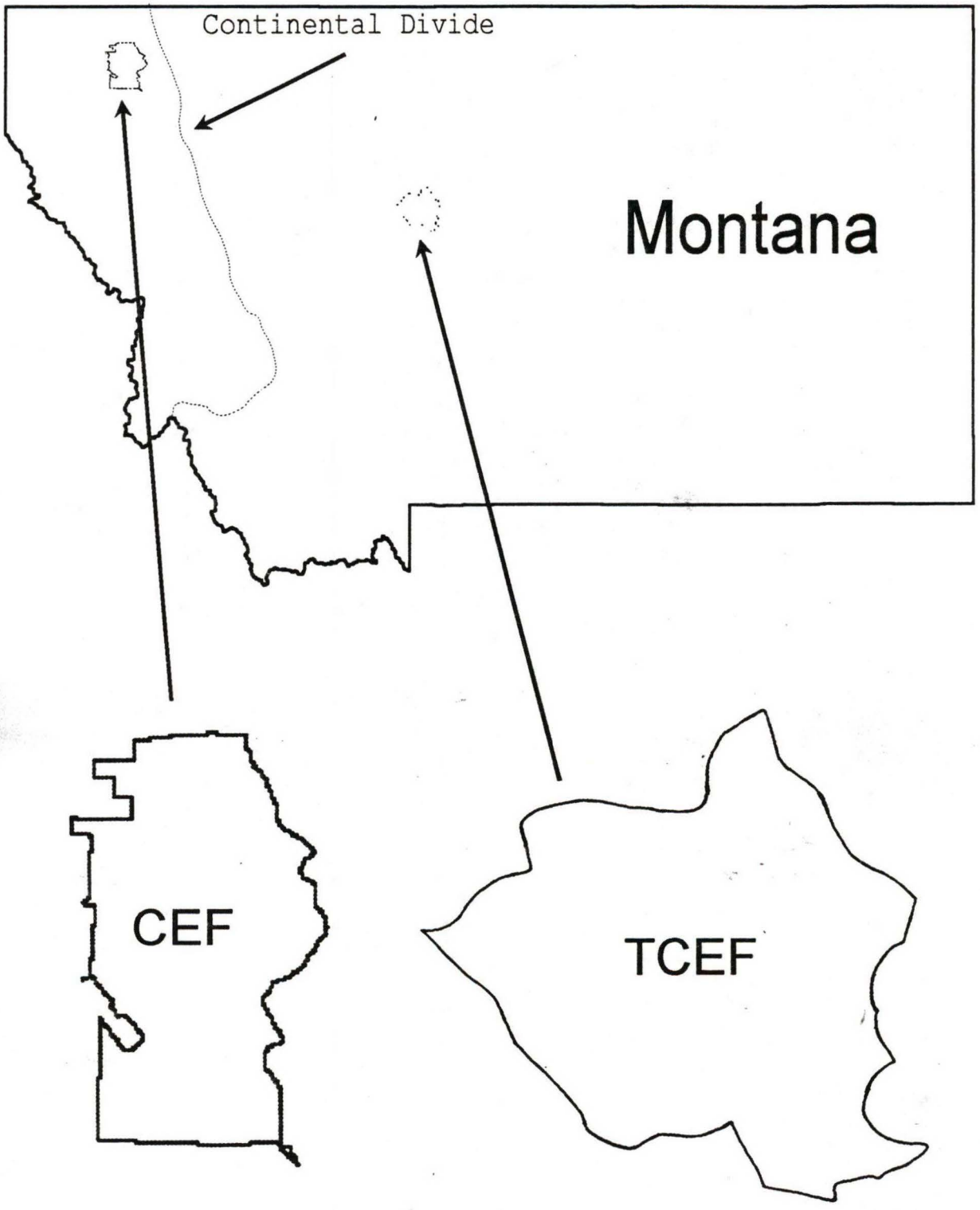



Figure 1. Location of Tenderfoot Creek Experimental Forest (TCEF) and Coram Experimental Forest (CEF).

## HISTORY OF TENDERFOOT CREEK EXPERIMENTAL FOREST

Tenderfoot Creek Experimental Forest (TCEF) was established in 1961 to implement watershed research for water yield and quality in subalpine east-side forests of the Northern Rockies. Access roads for installation of flumes were constructed in the early 1960s. Changes in research priorities precluded instrumentation in the 1960s. Some information such as soils, habitat types, timber stand inventories, flume locations, and sub-watershed boundaries were assembled between the 1960s and the 1980s. Activity on TCEF was expanded in 1991 with the new objective to develop and evaluate methods for sustaining the productivity and biodiversity of east-side lodgepole (Pinus contorta) communities. The new objectives were prompted by the increasing tree mortality and resulting high fuel-fire levels. This condition was occurring due to advancing age of most stands on the experimental forest. TCEF is to be a demonstration area for ecologically based treatments with emphasis on water quantity and quality. Treatment types and sizes will be determined after obtaining baseline information and evaluating the range of ecosystem processes for lodgepole pine communities. Collection of baseline data on all aspects of the ecosystem was initiated in the early 1990s.

## HISTORY OF CORAM EXPERIMENTAL FOREST

Coram Experimental Forest (CEF) was designated in 1933, and research was initiated in 1948. In 1937, a 1,100-acre Research Natural Area was set aside in the southeast corner of CEF to study long-term succession. It was designated a Biosphere Reserve in 1976. Research on CEF has been predominately related to response of timber stands to management activities. Various measurements of precipitation, snowpack, air temperatures, and soil moisture have been taken in conjunction with a wide range of studies and long-term monitoring (Hungerford and Schlieter 1984; Klages and others 1976; Newman and Schmidt 1980). In 1975, a flume was installed on Upper Abbot Creek. Stream flow measurements have since been continuous.

## PHYSICAL FEATURES OF TENDERFOOT CREEK EXPERIMENTAL FOREST

Lodgepole pine (Pinus contorta) dominate each of the four subalpine fir habitat types found within the TCEF. Other tree species occurring on the experimental forest are subalpine fir (Abies lasiocarpa), Engelmann spruce (Picea engelmannii), whitebark pine (Pinus albicaulis), and aspen (Populus tremuloides).

Soils are derived from argillites and quartzites. Glaciation has produced a broad basin-like topography in the upper elevations. Rock outcrops and talus slopes are common in lower elevations. Hornblende biotite gneiss is exposed in these areas. Flathead sandstone rests on top of the granite gneiss. Wolsey shale sits above the Flathead sandstone and is generally associated with gentler slopes in the headwater areas. Grassland parks are underlain by Wolsey shale and range from well to poorly drained. Seeps and springs are common in these areas. The highest elevation in the northeastern part of TCEF is porphyritic rhyodacite. The southeast portion of TCEF, Quartzite Ridge, is resistant quartzite that has been faulted upward from the Flathead sandstone formation. A detailed description of geology for TCEF,

prepared by Dr. Mitchell W. Reynolds of the U.S. Geological Survey, is shown in Hydrologic and Geologic Characterization of Tenderfoot Creek Experimental Forest by Farnes, McCaughey, and Hansen (1995).

Tenderfoot Creek Experimental Forest encompasses 8,874 acres according to the Lewis and Clark National Forest Geographic Information System. Elevations range from 6,030 to 7,944 feet with mean elevation of 7,236 feet. TCEF has a vertical relief of 1,914 feet. Elevation contours and subwatershed delineations for TCEF are shown in Figure 2. Distribution of elevations is shown in Figure 3.

The average annual precipitation map developed for the 1961-1990 base period for Tenderfoot Creek Experimental Forest (Farnes, McCaughey, and Hansen 1995) is shown in Figure 4. The 1961-1990 average annual precipitation for Tenderfoot Creek Experimental Forest is 34.8 inches. The distribution of average annual precipitation on TCEF is shown in Figure 5.

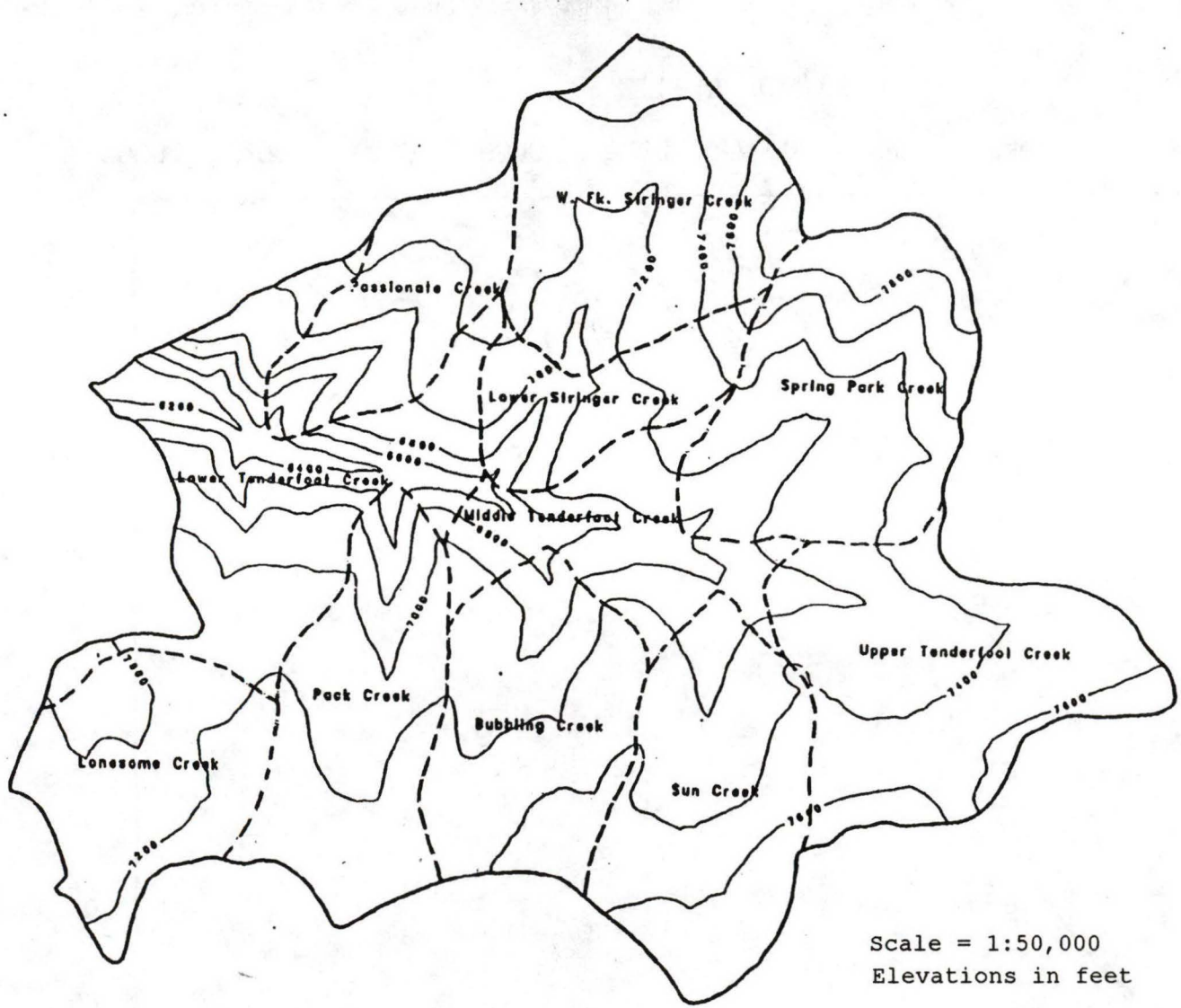



Figure 2. Map of elevations for Tenderfoot Creek Experimental Forest and subwatersheds.

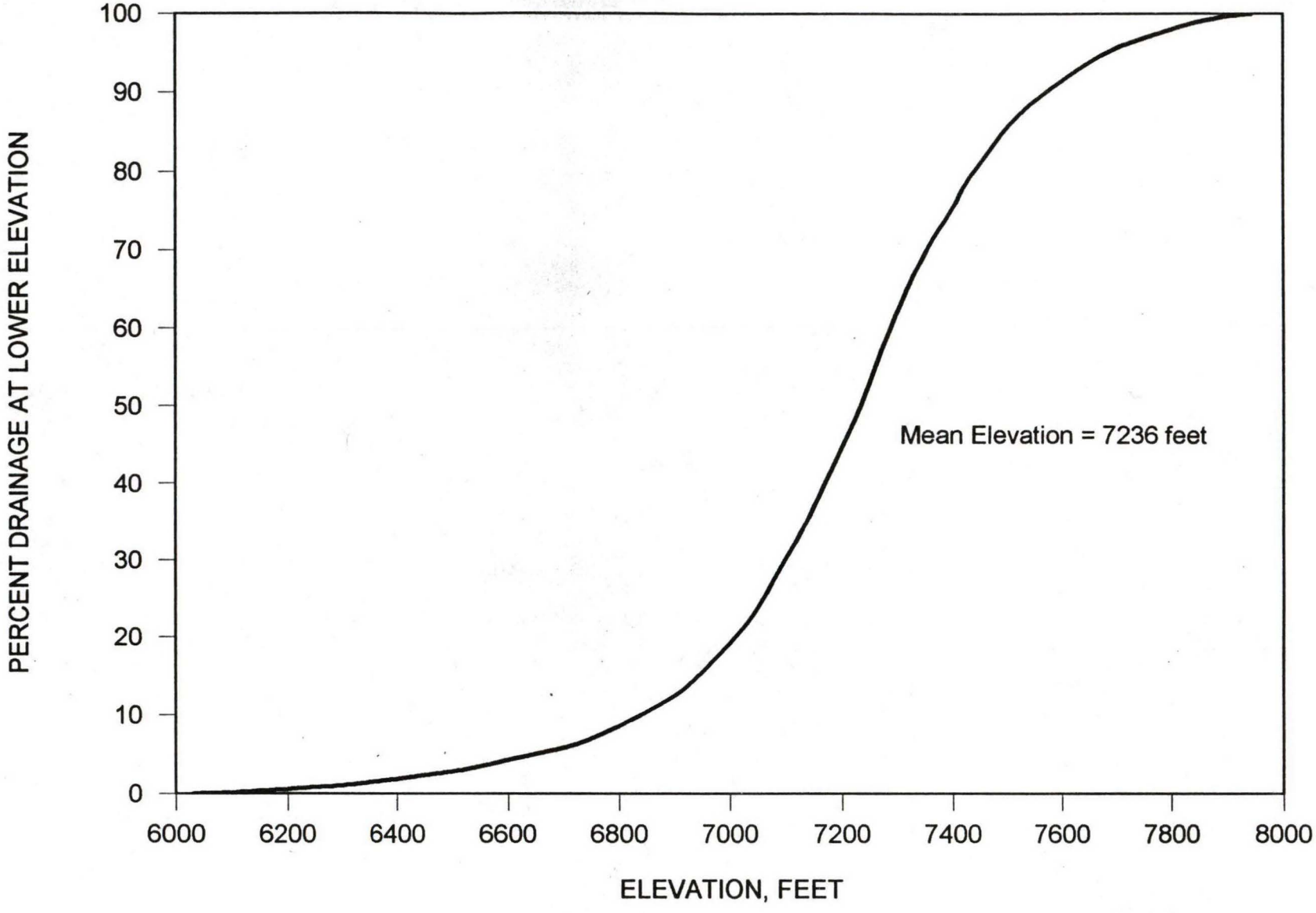



Figure 3. Area/elevation curve for Tenderfoot Creek Experimental Forest.

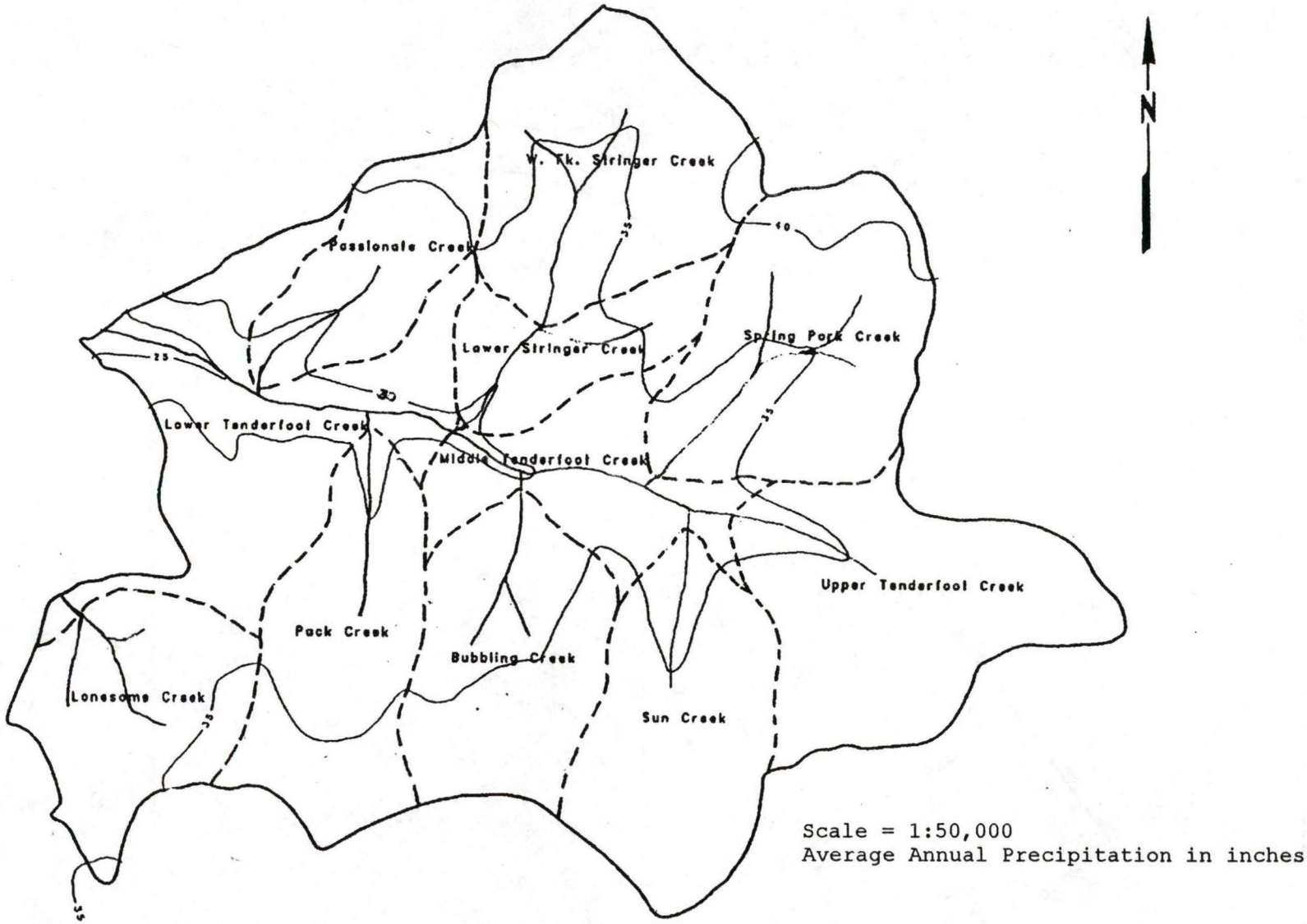



Figure 4. Map of 1961-90 average annual precipitation for Tenderfoot Creek Experimental Forest and subwatersheds.

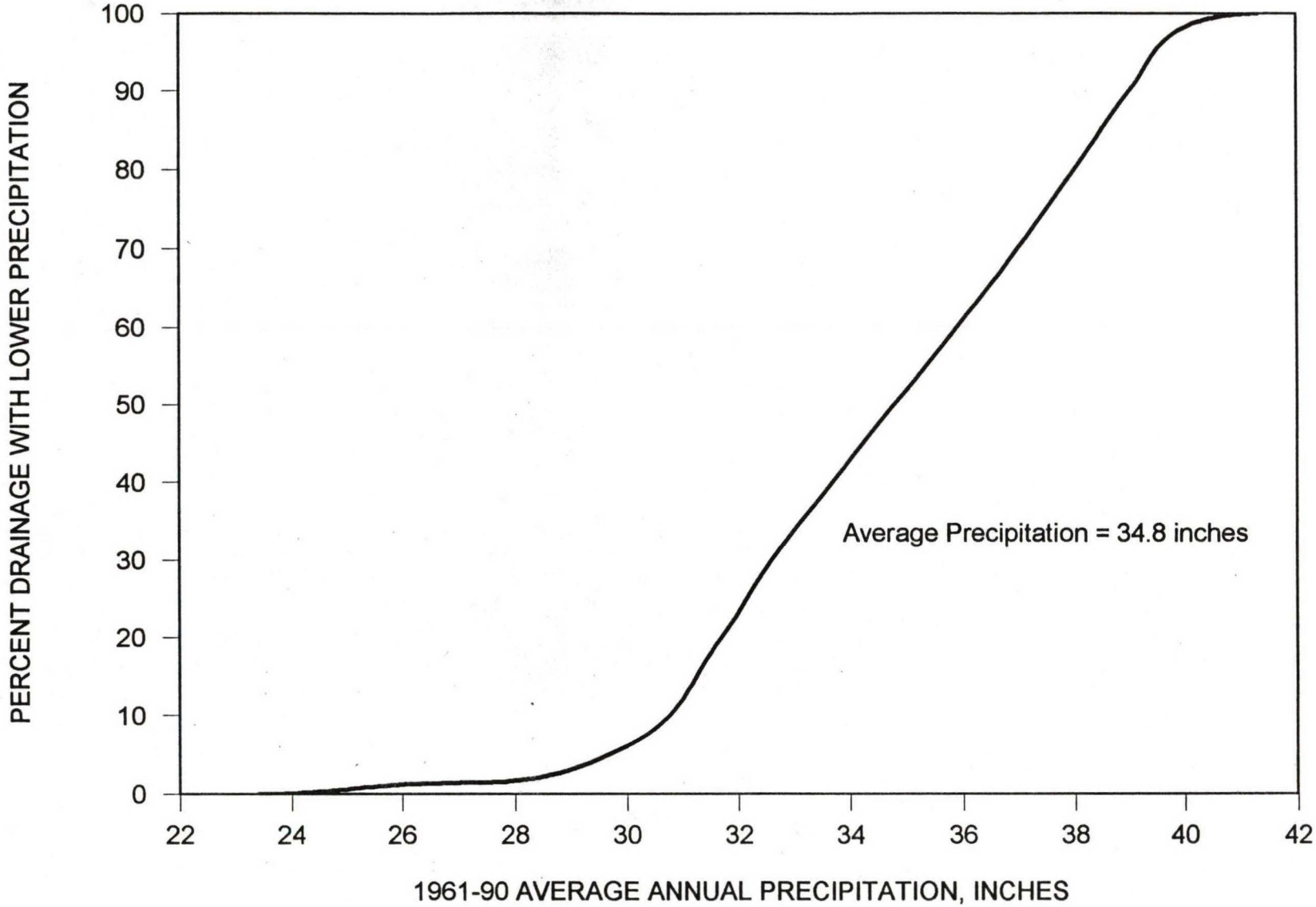



Figure 5. Area/precipitation curve for Tenderfoot Creek Experimental Forest.

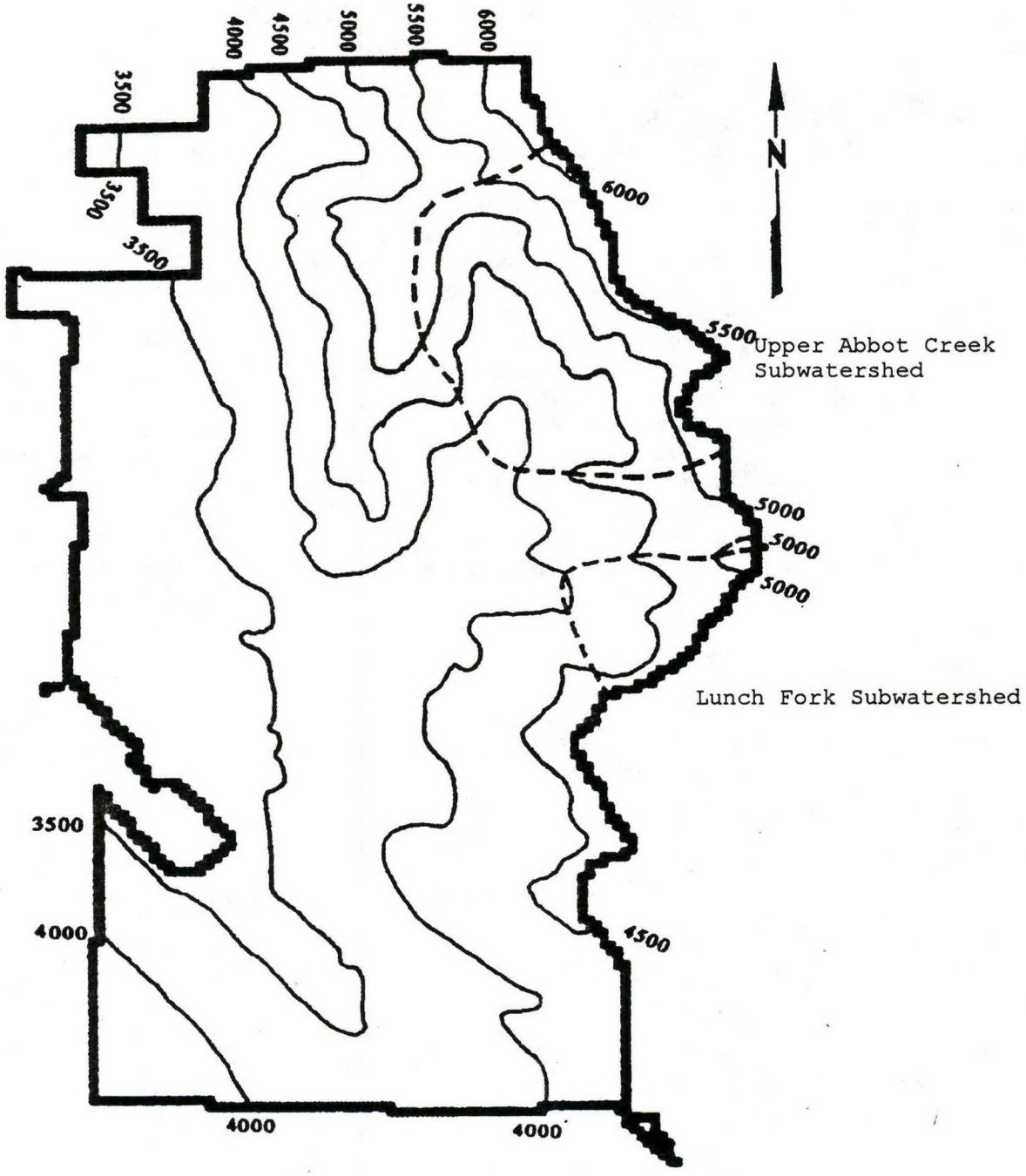
## PHYSICAL FEATURES OF CORAM EXPERIMENTAL FOREST

Even-aged western larch (*Larix occidentalis*) and Douglas-fir (*Pseudotsuga menziesii*) are the predominate tree species on CEF. The subalpine fir/queencup beadlily (*Abies lasiocarpa/Clintonia uniflora*) and Douglas-fir/ninebark (*Pseudotsuga menziesii/Physocarpus malvaceus*) habitat types predominate.

Soils are derived from limestone argillite and dolomite with glacial till deposited on the lower areas (Klages and others 1976). Geology in the area is limestone, dolomite, and argillite of the Helena Formation and Tertiary Kishenehn sediments. Detailed geologic information is not yet available for CEF.

Coram Experimental Forest has an area of 7,423 acres according to Flathead National Forest Geographic Information System. Elevations range from 3,280 to 6,436 feet with mean elevation of 4,039 feet. The vertical relief for CEF is 3,156 feet. Elevation contours and subwatershed delineations for CEF are shown in Figure 6. Distribution of elevations is shown in Figure 7.

The average annual precipitation map developed for the 1961-1990 base period for Coram Experimental Forest (Farnes, Shearer, and Hansen 1995) is shown in Figure 8. The 1961-1990 annual precipitation for Coram Experimental Forest is 37.2 inches. The distribution of average annual precipitation on CEF is shown in Figure 9.




CORAM EXPERIMENTAL FOREST
ELEVATION IN FEET

Scale = 1:50,000

Figure 6. Map of elevations for Coram Experimental Forest and subwatersheds.

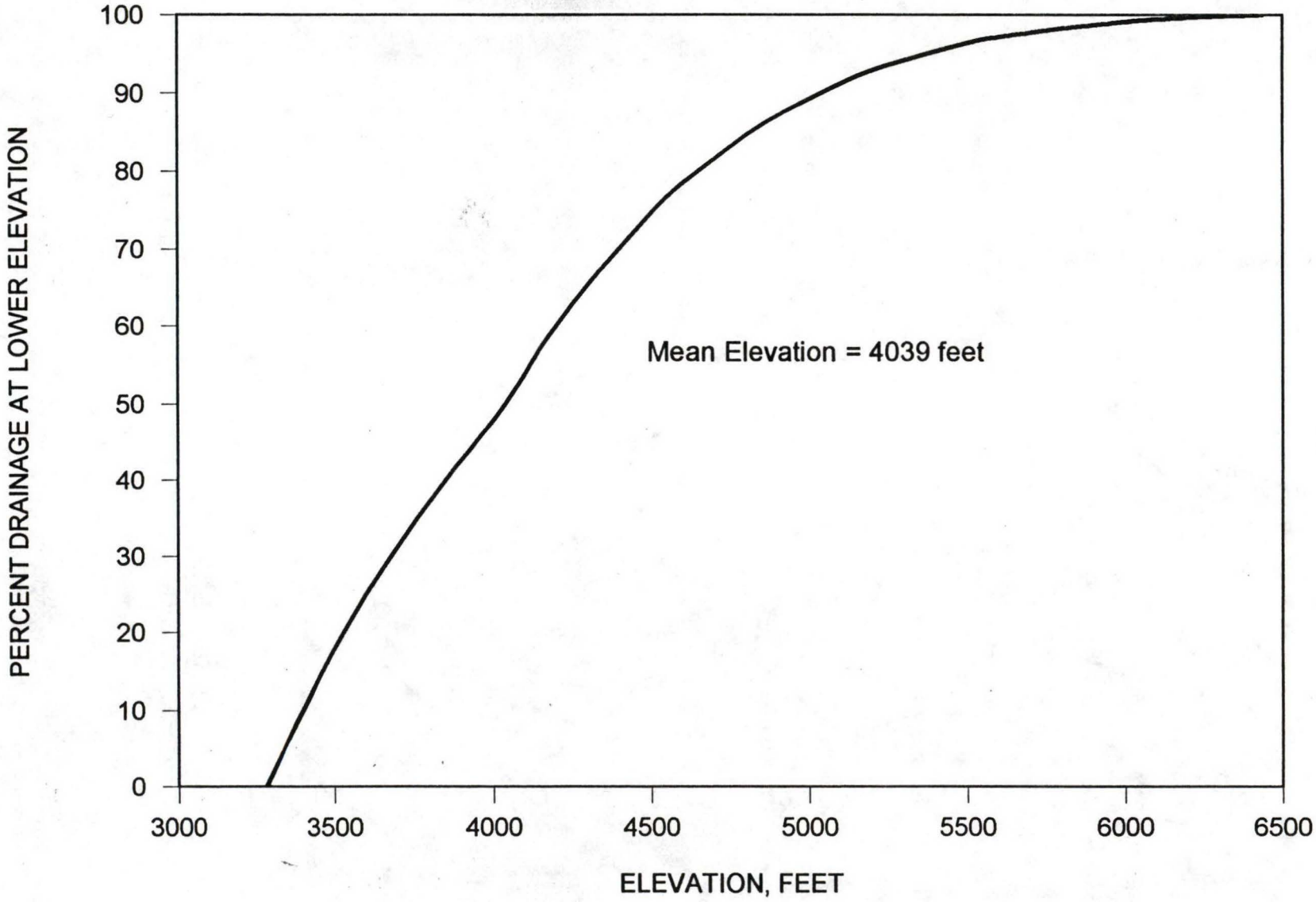
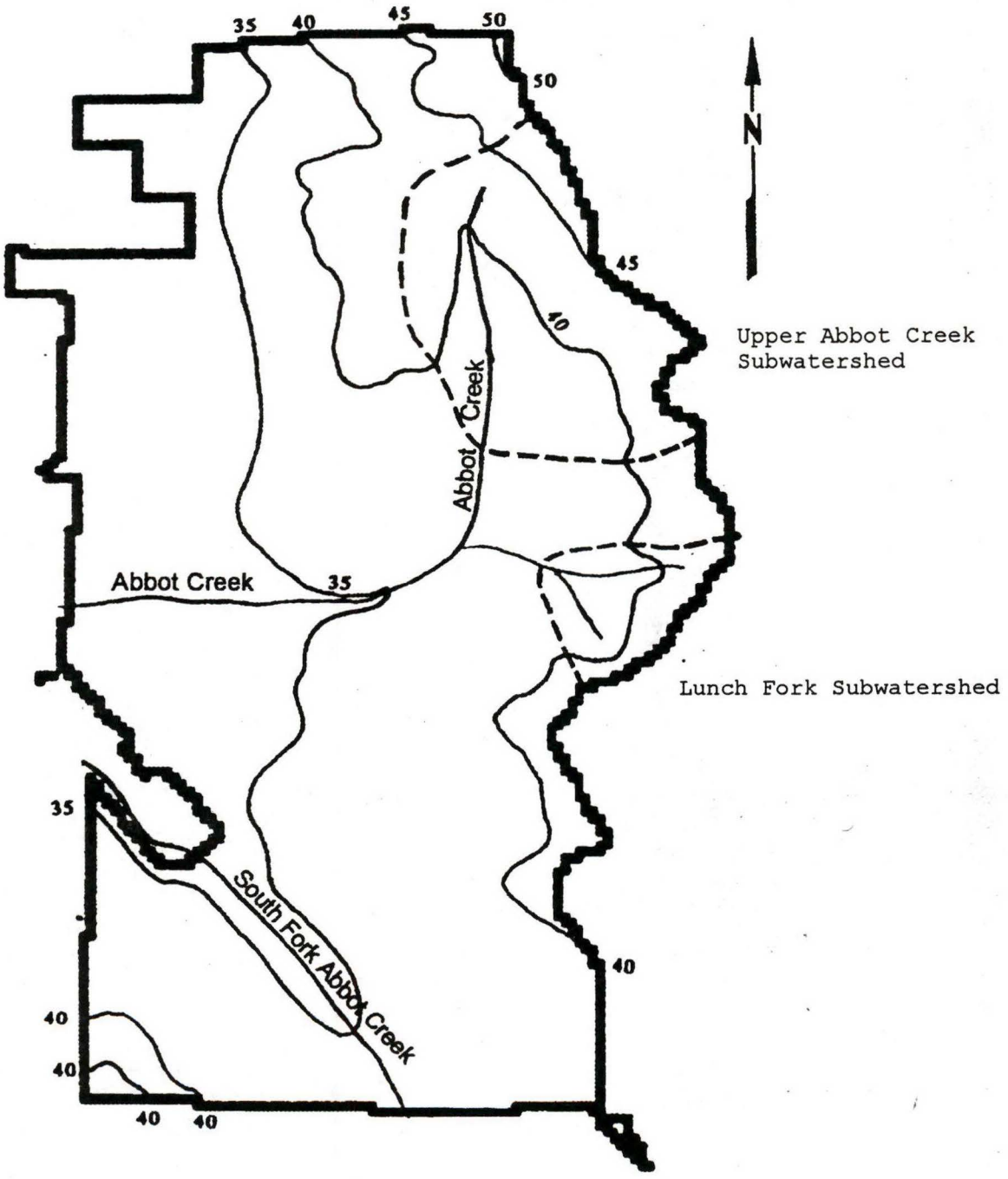



Figure 7. Area/elevation curve for Coram Experimental Forest.




CORAM EXPERIMENTAL FOREST
1961-90 AVERAGE ANNUAL PRECIPITATION
IN INCHES

Scale = 1:50,000

Figure 8. Map of 1961-90 average annual precipitation for Coram Experimental Forest and subwatersheds.

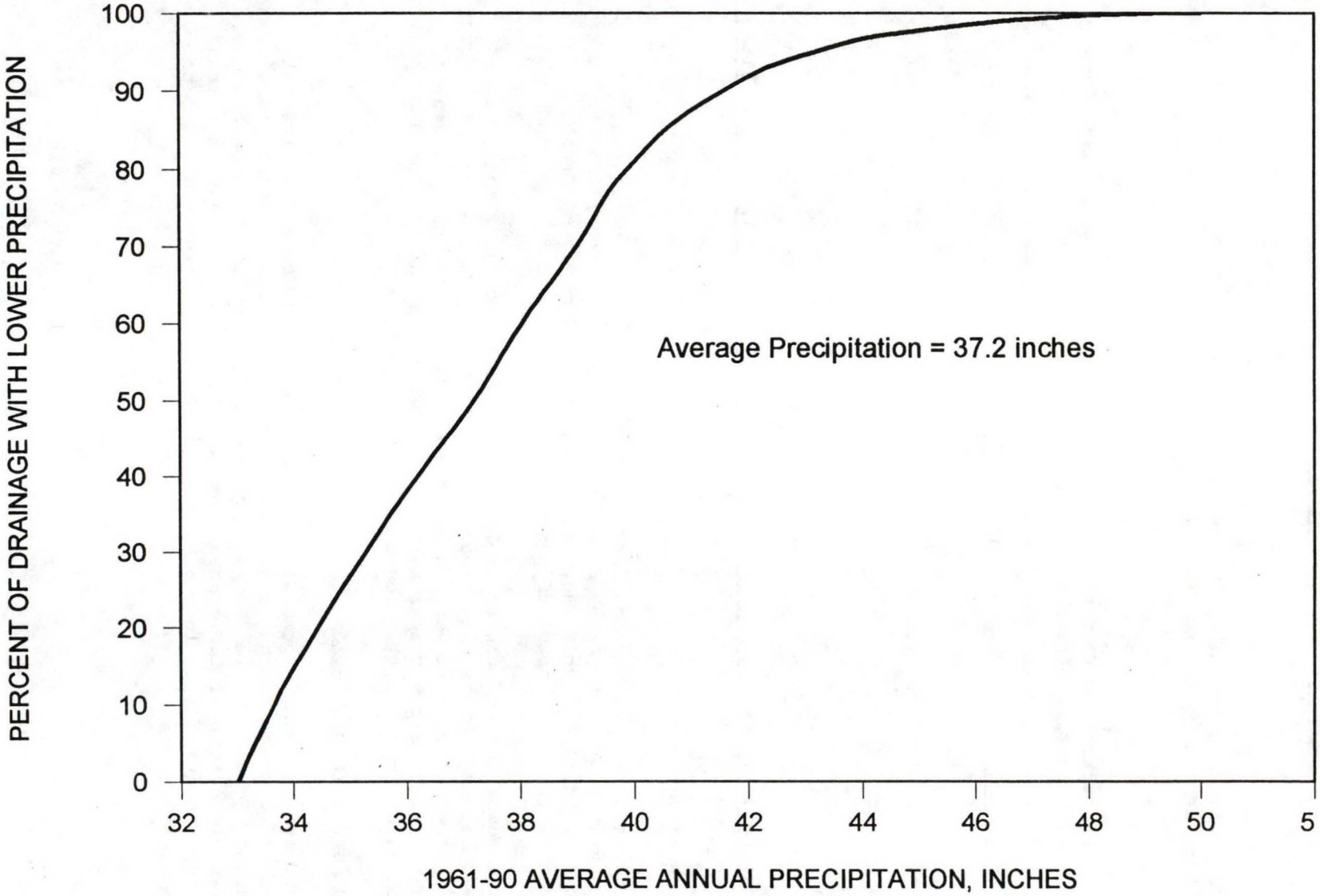



Figure 9. Area/precipitation curve for Coram Experimental Forest.

## COMPARISON BETWEEN THE EXPERIMENTAL FORESTS

### Area

Comparison of the area of TCEF and CEF is shown in Table 1. TCEF is about 20 percent larger than CEF.

Table 1. Comparison of Physical Characteristics Between Tenderfoot Creek Experimental Forest and Coram Experimental Forest.

| Physical Characteristics | TCEF | CEF |
|---|---|---|
| Drainage area, acres | 8874 | 7423 |
| Drainage, area, square miles | 13.9 | 11.6 |
| Mean elevation, feet | 7236 | 4039 |
| Highest elevation, feet | 7944 | 6436 |
| Lowest elevation, feet | 6030 | 3280 |
| Vertical relief, feet | 1914 | 3156 |

### Elevation

Comparison of elevations for TCEF and CEF is shown in Table 1. Elevations at Tenderfoot Creek Experimental Forest are higher than those of Coram Experimental Forest. The vertical relief of Tenderfoot Creek Experimental Forest is about 65 percent smaller than the relief of Coram Experimental Forest.

The lower part of the area-elevation curves (Figures 3 and 7) is different between the two experimental forests. The lower elevations of TCEF are in a steep, narrow canyon, while lower elevations of CEF represent a larger area with less vertical relief. Neither forest has a prominent peak, and both have timber at all elevations.

### Average Annual Precipitation

The average annual precipitation for Tenderfoot Creek Experimental Forest is 34.8 inches which is slightly lower than the 37.2 inches for Coram Experimental Forest (Table 2). Average annual precipitation in both higher and lower elevations of CEF exceed those at TCEF. The increase in average annual precipitation from lowest to highest elevation is similar on both experimental forests.

Table 2. Comparison of Precipitation Characteristics Between Tenderfoot Creek Experimental Forest and Coram Experimental Forest.

| Annual Precipitation | TCEF | CEF |
|---|---|---|
| 1961-90 average annual precipitation, inches | 34.8 | 37.2 |
| 1961-90 highest average annual precipitation, inches | 41.3 | 50.0 |
| 1961-90 lowest average annual precipitation, inches | 23.4 | 33.0 |
| **Distribution of Monthly Precipitation as Percent of Annual Precipitation** | | |
| October | 6 | 6 |
| November | 8 | 11 |
| December | 10 | 11 |
| January | 11 | 10 |
| February | 8 | 9 |
| March | 9 | 8 |
| April | 8 | 8 |
| May | 11 | 11 |
| June | 10 | 9 |
| July | 7 | 6 |
| August | 6 | 5 |
| September | 6 | 6 |
| **Distribution of Seasonal Precipitation as Percent of Annual Precipitation** | | |
| Winter precipitation (October - March) | 52 | 55 |
| Spring precipitation (April - June) | 29 | 28 |
| Summer-Fall precipitation (July - September) | 19 | 17 |

## Precipitation Patterns

The precipitation pattern is typical of the Northern Rocky Mountains. Over one-half of the annual precipitation occurs during October through March, and most falls as snow and is stored on the watershed until spring melt. Spring rains comprise a significant portion of the yearly precipitation while summers and falls are usually drier than other seasons. Annual and seasonal precipitation is variable.

The seasonal distribution of annual precipitation (Table 2) is similar on both experimental forests. However, CEF does receive a slightly greater component of winter precipitation. The relationship between area and precipitation across the two experimental forests is different in lower elevations (Figures 5 and 9). This is a function of the area/elevation relationship where the lower elevations of TCEF are a steep, narrow canyon. In these areas, precipitation increases rapidly with small increases in area. Through the middle elevations, both experimental forests have similar slope relationships between area and precipitation.

## Snowfall

Snow depth in upper elevations of TCEF can reach 8 feet, but the average for April 1 is about 5 feet. In lower elevations of TCEF, maximum depths can reach 5 feet but normally are about 3-1/2 feet on April 1. Snow depth in upper elevations of CEF can approach 6 feet, but average depths for April 1 are around 4 feet. At lower elevations of CEF, snow depths can reach 4 feet but average around 2 feet in March.

On TCEF, April 1 SWE is about 50 percent of average annual precipitation in higher elevations. On CEF, the April 1 SWE in higher elevations is about 45 percent of the average annual precipitation. In lower elevations, April 1 SWE in TCEF is about 35 percent of average annual precipitation. At CEF, April 1 SWE at lower elevations is about 30 percent of average annual precipitation.

## Temperature

The temperatures are consistently warmer at Coram Experimental Forest (Table 3). This is partly because of warmer climate and partly because of lower elevations at CEF. The area west of the Continental Divide (CEF) is somewhat shielded from cold arctic air that invades areas east of the divide during winter. Temperatures on both forests are highly variable. Lows on TCEF can range from -40°F or colder during the influx of these strong arctic frontal systems to maximum summer temperatures that may periodically reach the mid- to high-90's but are usually in the 70's. Inversions are common in the winter where temperatures are warmer in higher elevations than in the valleys.

At Coram Experimental Forest, minimum temperatures may be as low as -25°F to -30°F in lower elevations. However, some winters do not have temperatures below zero. Maximum annual temperatures are usually in the 90's but rarely do temperatures in lower elevations approach 100°F. Typical daily maximum temperatures in the summer are usually between 70°F and 85°F.

For TCEF, average daily lapse rates are about 1.5°F per 1,000 feet elevation with winter increments varying from -2°F to 2°F and summer increments about 2°F. Temperature inversions are more common on TCEF.

Table 3. Comparison of Mean Monthly Temperatures at Lower Elevations Between Tenderfoot Creek Experimental Forest and Coram Experimental Forest.

Extimated Mean Monthly Temperatures for Lower Elevations of Tenderfoot Creek and Coram Experimental Forest in °F

| | Daily Maximum | | Daily Minimum | | Daily Mean | |
|---|---|---|---|---|---|---|
| | TCEF | CEF | TCEF | CEF | TCEF | CEF |
| October | 51 | 52 | 19 | 31 | 35 | 42 |
| November | 39 | 37 | 7 | 24 | 23 | 30 |
| December | 27 | 30 | -2 | 18 | 12 | 24 |
| January | 23 | 27 | -5 | 13 | 9 | 20 |
| February | 28 | 34 | -1 | 18 | 14 | 26 |
| March | 33 | 40 | 4 | 21 | 18 | 31 |
| April | 48 | 51 | 15 | 29 | 34 | 40 |
| May | 56 | 63 | 24 | 36 | 40 | 49 |
| June | 65 | 70 | 32 | 43 | 48 | 56 |
| July | 76 | 79 | 39 | 46 | 58 | 62 |
| August | 74 | 70 | 39 | 45 | 56 | 61 |
| September | 61 | 66 | 30 | 38 | 46 | 52 |
| Annual | 48 | 52 | 17 | 30 | 32 | 41 |

Average daily lapse rates for CEF are about 3°F per 1,000 feet elevation with winter increments about 2.5°F and summer increments about 3.5°F.

The variation in temperatures between the daily maximum and daily minimum is greater at TCEF than at CEF. During winter months, the greater number of overcast days at CEF keeps the minimum daily temperatures near the daily maximum temperature while at TCEF daily minimums are much colder because of more days with radiation cooling under clear atmospheric conditions.

## Streamflow Patterns

Streamflows on both Tenderfoot Creek Experimental Forest and Coram Experimental Forest follow the typical pattern of snowmelt drainage. Peak flow on TCEF usually occurs from mid-May to early June and is associated with snowmelt and spring rains. The upper reaches of Abbot Creek in the northern part of CEF usually flows underground and surfaces about 300 yards upstream from the Abbot Creek flume. Streamflow at the flume is relatively constant, increasing slightly after snowmelt and spring rains and then decreasing slightly through the winter months. The annual volume is related to

precipitation and snowmelt input. Other streams on CEF (e.g., Lunch Fork) exhibit more normal seasonal distribution. The highest flows are usually in May and are associated with snowmelt and spring rains. On both forests (with the exception of Upper Abbot Creek) flows decrease significantly as summer progresses. Winter flows are typically the lowest of the water year. Precipitation during summer and fall is generally utilized by vegetation with little finding its way into streamflow.

Runoff

None of the streams on CEF have been monitored for flow except for Upper Abbot Creek. However, a flume was installed on Lunch Fork in the fall of 1994. TCEF has 7 flumes and 3 staff gages, most with 2 years of streamflow record.

Estimates of runoff from both forests have been made in Farnes, McCaughey, and Hansen (1995) and Farnes, Shearer, and Hansen (1995) using drainage area, average annual precipitation, and comparisons with locally gaged streams. Estimated runoff from CEF is nearly 3 inches greater than TCEF because of more precipitation. The total yield of runoff from CEF is slightly greater than for TCEF (Table 4).

Specific conductance (based on 10 field measurements) at Abbot Creek flume is generally in the 200 to 400 $\mu$S/cm range while most streams on TCEF have specific conductance in the 40 to 100 $\mu$S/cm. The upper portion of Tenderfoot Creek that drains the Onion Park Research Natural Area usually has specific conductance values nearly double those on other TCEF streams.

Suspended sediment concentrations are generally less than 20 mg/l during peak runoff and less than 5 mg/l at other times on TCEF streams. There have been no collection or analysis of suspended sediment on CEF.

Streamflows on CEF support predominately a brook trout fisheries while rainbow, cutthroat, brook and rainbow-cutthroat hybrid are present on TCEF.

Table 4. Comparison of Estimated Average Annual Water Yield Between Tenderfoot Creek Experimental Forest and Coram Experimental Forest.

| Estimated Water Yield | TCEF | CEF |
|---|---|---|
| Average annual water yield, inches | 12.0 | 14.8 |
| Average annual water yield, acre-ft | 8875 | 9150 |

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